09/762996

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PATENT TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
EO/US

Applicant(s) for EO/US: Fredrik LIDÉN; and
Magnus ÖBERG

U.S. Serial No.: (Not Yet Assigned)
U.S. Filing Date: (Herewith)

International Application No. PCT/EP99/05630
International Filing Date: 03 August 1999

Priority Date: 14 August 1998
Priority Application: EP 98 115 369.5

Title of Invention: WAVELENGTH CONTROL IN OPTICAL WDM
SYSTEMS

Box DO/EO/US
Assistant Commissioner for Patents
Washington, D.C. 20231

CERTIFICATE OF MAILING BY EXPRESS MAIL

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Date of Deposit: .... FEBRUARY 13, 2001

I hereby certify that this paper, including the documents referred to
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Type or Print Name: Sara J. Morrison

Signature: Sara J. Morrison

Sir:

REQUEST FOR PCT NATIONAL ENTRY IN THE UNITED STATES
UNDER 35 U.S.C. 371 AND 37 CFR 1.495

This is an express request to begin national examination procedures of International Application Number PCT/EP99/05630 under 35 U.S.C. 371 and 37 CFR 1.495 in the United States Patent and Trademark Office.

09/762996

Inventor: Fredrik LIDÉN et al.
Attorney Docket No.: 50364-04USPX
Express Mail No.: EL 487169785 US

1. ☒ Enclosed are 16 pages of the specification, 7 pages of claims, and 1 page containing the abstract of International Application No. PCT/EP99/05630 as published.

2. ☒ Two sheets of formal drawings are enclosed.

3. ☒ The name(s), mailing address(es) and citizenship of the inventor(s) for this national application are not known to have changed since the publication of the International Application, and specifically are last known to be as follows:

Inventor	Name	Address	Country of Citizenship
(1)	Fredrik LIDÉN	Åldermannavägen 96 145 57 Norsborg SWEDEN	SWEDEN
(2)	Magnus ÖBERG	Pettersbergsvägen 16A 129 40 Hägersten SWEDEN	SWEDEN

4. ☒ The International Application was filed and examined in the English language.

5. ☐ An Article 19 Amendment was made in the International Application.

6. ☒ The International Bureau confirmed that it had received a certified copy of priority application EP 98 115 369.5 as filed on August 14, 1998 during the international stage of this PCT application by mailing Form PCT/IB/304 to the Applicant indicating such.

7. ☒ A proper Demand for International Preliminary Examination of the international application was made by the 19th month from the earliest claimed priority date. The United States was elected in the Demand. The International Bureau reported to the Applicant(s) that it had notified the EO/US in accordance with PCT Article 31(7) of its election for Chapter II proceedings.

8. ☐ A Combined Declaration with Power of Attorney document is enclosed.

9. ☒ An Information Disclosure Statement Under 37 CFR § 1.97(b) is enclosed, along with PTO Form 1449 and a copy of each reference identified on PTO Form 1449.

10. ☐ A Preliminary Amendment is enclosed.

11. ☒ In determining the Basic Fee for this application, the following information was considered:

Searching Authority   European Patent Office

Examining Authority   European Patent Office.

12. ☒ The filing fee is calculated by adding the appropriate Basic Fee to the fees for the number and types of claims presented for national entry under 37 CFR 371, specifically:

FOR	NUMBER FILED		NUMBER EXTRA	RATE		CALCULATION	
TOTAL CLAIMS	24	-20=	4	x $ 18.00	=	$	72.00
INDEPENDENT CLAIMS	2	-3=	-1	x $ 80.00	=	$	0
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				x $ 270	=	$	270
				BASIC FEE	+	$ 860.00	
			TOTAL OF ABOVE CALCULATIONS =			$	932.00
REDUCTION BY ½ FOR FILING BY SMALL ENTITY (Note 37 C.F.R. 1.9, 1.27, 1.28).						0	
				Total =		$	932.00

13. ☐ A check is enclosed.

14. ☒ The Commissioner is hereby authorized to charge all fees associated with this application under 37 C.F.R. §1.16 and §1.17 to Deposit Account No. 10-0447, reference 50364-04USPX. A duplicate copy of this sheet is enclosed.
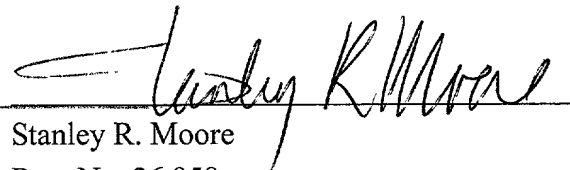
15. ☒ Also enclosed:

    1.   Certificate of Express Mailing No. EL 487169785 US; and

    2.   Confirmation Postcard.

16. ☒ Address all future communications to:

<div align="center">

Stan R. Moore, Esq.
JENKENS & GILCHRIST, P.C.
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</div>

Respectfully submitted,
JENKENS & GILCHRIST, P.C.

Stanley R. Moore
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Date: February 13, 2001

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COMPLETION FEES

A check in the amount of $220 is enclosed for payment of the surcharge fee for filing of the Declaration subsequent to the filing of the patent application ($130) and additional claim fees ($90).

The Commissioner is hereby authorized to charge the following additional fees that may be required by this paper and during the pendency of this application or to credit any overpayment in connection herewith to deposit account number 10-0447 of JENKENS & GILCHRIST, P.C. for any of the following fees:

(1)   37 CFR §1.16(a) for filing fees;

(2)   37 CFR §1.16(b), (c) and (d) for presentation of extra claims;

(3)   37 CFR §1.16(e) for payment of the surcharge fee;

(4)   37 CFR §1.17(a)(1)-(5) for payment of extension fees pursuant to §1.136(a); and

(5)   37 CFR §1.17 for payment of application processing fees.

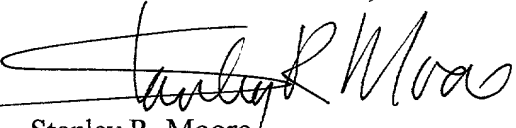A duplicate of this request is attached.

07/18/2001 TNGUYEN 00000152 09762996
01 FC:154   130.00 OP
02 FC:966   90.00 OP

08/10/2001 ATRAN1   00000063 100447   09762996
01 FC:116   390.00 CH

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
DO/EO/US

Applicant(s):   Fredrik LIDÉN et al.

U.S. Serial No.:   09/762,996
U.S. Filing Date: August 3, 1999

Examiner: Not Yet Known
Group Number: Not Yet Known

Title of Invention: WAVELENGTH CONTROL IN OPTICAL
                                 WDM SYSTEMS

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Assistant Commissioner for Patents
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Type or Print Name: Carla Elkins
Signature</td></tr>
</table>

Madam or Sir:

RESPONSE TO NOTICE OF MISSING REQUIREMENTS
UNDER 35 U.S.C. 371 IN THE DO/EO/US

This is a response to the Notification of Missing Requirements under 35 U.S.C. 371 in the United States Designated/Elected Office (DO/EO/US) mailed on March 9, 2001.

Enclosed is a copy of the Notification of Missing Requirements under 35 U.S.C. 371 in the United States Designated/Elected Office (DO/EO/US). Enclosed is the original combined Declaration and Power of Attorney for this application signed by Inventors Fredrik LIDÉN and Magnus ÖBERG.

Wavelength control in Optical WDM systems

1. Field of the Invention

10

The invention relates to wavelength division multiplexed optical communication systems and, in particular, to the measurement and control of wavelengths transmitted by an optical transmission source and received by an optical

15   wavelength selective element.

2. Background Art

20

In wavelength division multiplexed (WDM) optical communication systems, a single fibre optic cable carries a plurality of optical signal channels, each channel being assigned a particular carrier wavelength. The signal channels are generated using wavelength specific lasers. These channels are then coupled to the traffic

25   fibre using an optical combiner or multiplexer and sent to the next node in the system, possibly via a number of optical amplifiers. At the receiving node, the different wavelengths are filtered out in a demultiplexer and are sent to a respective receiver where they are converted to

30   electrical signals and relayed to further systems or networks.

In the demultiplexer, individual optical channels must be selected from the multiplexed optical signal. To ensure

35   that an optical signal is properly selected, the carrier wavelength launched by the laser transmitter must accurately match the wavelength selected in the demultiplexer. Although the lasers are generally very stable in terms of wavelength, erroneous operation can

lead to wavelength drift in an individual channel over time. Similarly, the wavelengths of the demultiplexer passbands can drift. It is important that this wavelength drift is detected and corrected before the channel has deteriorated so much that traffic is disturbed in the channel itself as a result of attenuation, and in neighbouring channels by crosstalk. This is particularly important for dense WDM systems wherein the wavelength spacing between channels is very small, often of the order of a nanometer.

A technique for dynamically stabilising a wavelength selective element in a WDM system is described in US-A-5 673 129. This document describes that a wavelength reference is used to stabilise the output wavelength of a transmission laser while the reflection wavelength of a Bragg grating used as a wavelength selective element at the receiving end of the system is dynamically adjusted to obtain the maximum reflected optical signal and so accurately correlate the Bragg grating to the corresponding transmitted wavelength. The adjustment of the Bragg grating reflection wavelength is obtained by temperature tuning or adjustment of the amount of physical tension applied to the Bragg grating.

While this arrangement ensures the accurate correlation of the wavelength selective element to the transmitted wavelength, an extreme drift in wavelength in an individual laser will not be corrected and could ultimately lead to crosstalk between adjacent channels. Furthermore, the need for a wavelength reference for each laser necessitates the provision of a relatively large number of potentially costly components.

5   In an alternative embodiment described in the same patent, the temperature of the Bragg grating is held constant and the signal reflected at the grating is fed back to the transmitting laser and used to dynamically tune the laser to the reflected wavelength by adjustment

10 of the laser temperature. However, the provision of a stable temperature environment for the Bragg grating without recourse to adjustment on the basis of variations in the reflected wavelength is difficult to implement and is dependent on the reliability of normally electrical

15 heating and cooling elements.

In the light of the disadvantages associated with the prior art it is an object of the present invention to provide an arrangement and procedure for controlling the

20 wavelengths of channels in an optical WDM system which is reliable, simple and inexpensive in its implementation.

SUMMARY OF THE INVENTION

25 To control the wavelengths of channels transmitted by one or more optical sources and received by a wavelength selective element, the present invention proposes a method wherein at the receiving end a value of a wavelength influencing parameter of the wavelength

30 selective element that enables the best reception of the channel is determined. This value is then utilised to ascertain whether the wavelengths used in the link have drifted. This parameter value associated with the channel centre wavelength is accurately located by determining

35 two parameter values at which the output power drops by a predetermined amount, and then calculating the central value. When the parameter values are difference values relative to a nominal starting value, the mean averaged over all channels serves as an indicator of wavelength

drift in the link. By determining the proportion of
channels demonstrating wavelength drift, both the source
and magnitude of the wavelength drift can be ascertained
and corrected either by adjusting the parameter value of
the wavelength selective element or by adjusting the
wavelength launched by one or more lasers. A wavelength
control arrangement for use in an optical WDM link
according to the invention is characterised by control
means that communicate with a parameter regulator of the
wavelength selective element that is adapted to regulate
a wavelength influencing parameter and with means that
monitor the output power of the wavelength selective
element. The control means are furthermore coupled to a
regulator adapted to regulate a wavelength influencing
parameter of a laser and laser drive circuit and are
adapted to determine the magnitude and source of a
wavelength error and subsequently control one or both of
the wavelengths launched by the lasers and the
wavelengths received by the wavelength selective element.

Advantageously, the method and arrangement according to
the present invention permit wavelength drift to be both
detected and corrected whether caused by one or more
malfunctioning lasers or by the wavelength selective
element when the parameter utilised is temperature,
wavelength drift at the wavelength selective element
could, for example, result from the deterioration of
associated electrical temperature regulating elements.
Furthermore, the method obviates the need for permanent
wavelength references at the optical sources or lasers,
but nevertheless permits wavelength drift to be
determined and corrected with high precision. The control
measurement can be performed entirely at the receiving
end of the link without impeding or degrading normal
traffic flow. A further advantage of the method and

5   arrangement according to the present invention is that
       the division of the channels received by the wavelength
       selective element does not need to precisely match the
       transmitted wavelengths. The best average power for all
       channels can be defined and maintained using the method
10   and arrangement according to the invention.

       BRIEF DESCRIPTION OF THE DRAWINGS

       Further objects and advantages of the present invention
15   will become apparent from the following description which
       describes the preferred embodiments by way of example
       with reference to the accompanying drawings in which:

       Fig. 1   schematically depicts a 16 channel
20   optical wavelength division
                           multiplexed system,

       Fig. 2   schematically shows the control
                           system for controlling matching of
25   wavelength between the transmitting
                           optical sources and the demultiplexer
                           filter,

       Fig. 3   shows the typical transmission
30   characteristics of an arrayed
                           waveguide grating utilised as a
                           demultiplexer filter, and

       Figs. 4 and 5   show flow diagrams of the procedure
35   for determining and correcting
                           wavelength shift between optical
                           source lasers and the demultiplexer
                           filter.

5   DETAILED DESCRIPTION OF THE DRAWINGS

        The WDM link depicted in Fig. 1 includes a plurality of
        WDM transmitters 10, each adapted to transmit data
        signals modulated on a specific transmission wavelength.
10   The transmitters 10 each comprise a wavelength specific
        laser 110 (see Fig. 2) for launching the carrier
        wavelength. The multiple channels are coupled to a
        traffic cable 30 by a multiplexer 20 and are sent to the
        receiving node possibly via a number of amplifiers 40 if
15   the distance between the nodes is large.

        At the receiving node, the channels are split by a
        demultiplexer filter 50. In the exemplary embodiment the
        demultiplexer filter is an arrayed waveguide grating
20   (AWG) in silicon dioxide on silicon (SiO_2 on Si), however
        it will be understood that other materials and also
        alternative wavelength selective elements may be
        employed. The divided channels are then passed on
        individual cables to corresponding WDM receivers 80, of
25   which only one is illustrated here for convenience.

        The light signals of the individual channels output from
        the demultiplexer filter 50 are also monitored using
        detectors 70. One detector 70 only is illustrated in the
30   figure for clarity, however, it will be understood that a
        detector 70 will typically be coupled to each outgoing
        channel. Alternatively, a single detector could monitor
        the light signals from all outgoing channels in sequence.
        The detectors 70 can be any optical detector that
35   converts an optical signal into electrical energy such as
        a PIN diode detector, and are typically coupled to the
        optical transmission line using optical taps 60 that
        divert a small portion of the incident power towards the
        associated detector 70.

5

The components of the wavelength control system are shown in Fig. 2. In this figure like reference numerals have be used for like elements shown in Fig. 1. The elements include, at the receiving end of the optical link shown

10   in the lower half of Fig. 2, the demultiplexer filter constituted by an arrayed waveguide grating (AWG) filter 50, the detectors 70 coupled to each outgoing channel of the AWG filter 50 by a respective optical tap 60 (here again only one detector 70 and fibre tap 60 are

15   illustrated for convenience), a temperature regulator 90 associated with the demultiplexer filter 50 and a wavelength controller 100. The temperature regulator 90 is a device for varying the temperature of the AWG filter 50 and may comprise a heater, a cooler or a combination

20   of the two, including, but not limited to, resistive heaters and thermoelectric coolers.

The wavelength controller 100, which typically may comprise a microprocessor with associated memory, is coupled to the output of the detectors 70 and the

25   temperature regulator 90. The controller 100 is likewise coupled to each transmitter 10 of the optical link, only one of which is illustrated here, via a service or control channel 150 indicated by a dashed-dotted line in

30   Fig. 2. In each transmitter 10, the controller 100 communicates with a laser drive circuit 140, which supplies bias current to a laser 110 and with a laser temperature regulator 130. The laser is typically a distributed feedback laser (DFB) although it will be

35   understood that other types of laser can also be utilised. The laser temperature regulator incorporates a thermal/cooling element, such as a Peltier element or the like, for varying the temperature of the laser and accordingly adjusting the emitted wavelength. In

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alternative laser types the emitted wavelength may be controlled by adjusting electrical current to the laser or by the mechanical movement of optical elements, for example to increase or reduce strain. It will therefore to be understood that appropriate means of adjustment can be provided to an alternative laser in place of the arrangement described with reference to the figures. The transmitter 10 further includes a modulator 120 for modulating information data on the carrier signal.

It should be noted that while in Fig. 2 the controller 100 is shown disposed at the receiving end of the optical link it may also be placed at the transmitting end, in which case it would communicate with the detectors 70 and the temperature regulator 90 at the receiving end via the service channel 150. Alternatively the controller 100 may be located remote from both ends of the link.

A typical transmission characteristic of a demultiplexer filter 20 suitable for use in an optical WDM link is shown in Fig. 3. In the example shown, the passband wavelengths correspond to the International Telecommunications Union (ITU) standard wavelengths defined in the 1500 nm telecoms window. It is possible to adjust the passband wavelengths of the filter 20 by varying the demultiplexer temperature. For an AWG filter in SiO_2 on Si, the variation in passband wavelength is of the order of 0.012nm per degree Celsius. Since the transmission of the demultiplexer is wavelength dependent, the signal power to each detector 70 will vary with the temperature of the demultiplexer. It is possible to determine the temperature accurately, and in this way to indirectly measure the wavelengths of the incoming channels relative to one another. Specifically, the centre wavelength of a transmitted channel is ascertained

5   by determining the temperature of the demultiplexer
       filter 50 at which this wavelength is transmitted. In
       this manner both wavelength drift of one or more
       individual channels and temperature variation in the
       demultiplexer can be detected accurately.

10

       While the embodiment shown in the figures and described
       above is applied to the case wherein the passband
       wavelengths of the demultiplexer filter 50 vary with
       temperature, it will be understood that other

15   demultiplexer filters may be utilized which have a
       passband wavelength dependent on other parameters,
       including, but not limited to electrical injection
       current or mechanical movement of optical elements. With
       such a device the determination and measurement of

20   wavelength drift will be achieved by varying the
       appropriate wavelength influencing parameter of the
       demultiplexer filter 50. Accordingly the temperature
       regulator 90 of the demultiplexer filter 50 will be
       replaced, or supplemented by an appropriate regulator or

25   regulators for varying the parameter of interest. A
       similar parameter regulator can be employed at the
       transmitter 10 for adjusting the wavelength of the laser
       in place of, or in addition to the temperature regulator
       130.

30

       The method for controlling wavelength using temperature
       adjustment is described below. It should be noted that
       for devices with wavelength influencing parameters other
       than temperature an analogous method could be used.

35

       Prior to operating the link the lasers are first adjusted
       to the desired nominal wavelengths. In an optical WDM
       network the nominal wavelengths preferably conform to the
       ITU standard for the 1500nm telecoms window. The

5   adjustment is effected using a well calibrated external
       measuring instrument such as an optical wavelength meter
       or the like. Since the division of the demultiplexer
       filter 50 channels may not exactly match the
       predetermined nominal wavelengths, it may not be possible
10   to obtain maximum power for all channels at the
       demultiplexer filter 50. To adjust for this eventuality,
       the feedback loop constituted by the controller 100, the
       temperature regulator 90 and the detectors 70 is used to
       set the temperature of the demultiplexer filter 50 to
15   obtain the optimal mean output power from all utilised
       channels. To this end, the controller 100 performs an
       appropriate step algorithm which adjusts the temperature
       of the wavelength selective element until the mean output
       power from all channels is optimised. Note that the mean
20   output power need not be the median of the individual
       output powers, but could be weighted to ensure that no
       individual channel falls below a predetermined threshold
       level. It should be noted that in the following method
       the number of channels is indicated by n. In the
25   embodiment illustrated in Figs. 1 and 2, therefore, n
       goes from 1 to 16.

       Once both the nominal wavelengths and the initial
       temperature have been defined and fixed, the controller
30   100 calculates the initial variance (IVn) for each
       channel. This value corresponds to the difference between
       the temperature of the selective element when it
       transmits the optimum mean power of all channels and its
       temperature when it transmits a single channel optimally.
35   The initial variance value (IVn) for each channel is
       obtained using the procedure A illustrated in Fig. 4. In
       step 401 the starting temperature of the wavelength
       selective element, which in this case is the temperature
       for optimal average transmission of all nominal

5   wavelengths, and the power level of each channel is
        stored. The starting temperature may be an absolute
        temperature value, but it is preferable that this
        temperature be set to a nominal value, e.g. 0. The
        temperature of the demultiplexer filter 50 is incremented
10   in step 402. In step 403 the power level of each channel
        at the output of the demultiplexer filter 50 is compared
        with the initial output power. If it has fallen below
        0.5dB, the temperature is stored (step 405) if not, the
        method returns to step 402 and the temperature of the
15   demultiplexer filter 50 is incremented again. This
        continues until the power levels of all channels have
        fallen below the 0.5dB level and the corresponding
        temperatures of the demultiplexer 50 is stored. In
        practice the stored temperatures will be quantized values
20   corresponding to the number of temperature increments.
        The demultiplexer filter 50 is then returned to the
        starting temperature in step 405. In step 406, the
        temperature of the demultiplexer filter 50 is
        decremented. In step 407 the output power level of each
25   channel is measured and compared with the initial power
        level to determine whether it has dropped by 0.5dB. If
        not, the method returns to step 406, otherwise, the
        corresponding temperature is stored. This continues until
        two temperature values (DHn and DLn) corresponding to the
30   -0.5dB power levels have been determined for all
        channels. The mean IVn õf these two values (DHn, DLn) for
        each channel computed in step 409 then corresponds to the
        difference in temperature of the demultiplexer filter 50
        for transmitting the mean optimal power of all channels
35   and the optimal power of the channel in question when the
        channels are tuned to the predetermined nominal
        wavelengths. By inference, this mean variance value IVn
        likewise corresponds to the initial wavelength error for
        each channel. The mean value IVn is then stored for each

5   channel in the controller 100 for use in the subsequent
       wavelength checks.

       When the temperature values (DHn, DLn) are difference
       values relative to the starting temperature, then,
10   providing the centre wavelength of the filter 50 lies
       within the 0.5dB levels of the actual launched channel,
       one value DHn will be positive and the other DLn
       negative. Accordingly if the launched centre wavelength
       is exactly equal to the centre filter wavelength, the
15   initial variance value IVn will be zero. Note that since
       the temperature of the demultiplexer filter 50 has been
       adjusted for optimal average output power for all
       channels, the mean of these variance values IVn for all
       channels will be zero at this stage.

20   The initial starting temperature of the demultiplexer 50
       determined as described above is the ideal operating
       temperature and is consequently maintained using
       conventional electrical thermal and cooling elements and
       a suitable control circuit which is not shown. With time,
25   however, these electrical elements may deteriorate,
       causing the real temperature of the demultiplexer filter
       50 to vary and hence the passbands of the filter 50 to
       shift in wavelength. Errors leading to drift in
30   wavelength may also arise in individual lasers 110.

       Hence, during operation of the optical WDM link the
       correlation between the launched wavelengths and the
       wavelengths transmitted through the demultiplexer filter
35   50 is checked at regular intervals using the procedures
       laid out in Figs. 4 and 5. Firstly, steps 401 to 409 of
       procedure A are followed as described above with, in this
       case, the starting temperature being the actual
       temperature of the demultiplexer filter 50 at the time of

measurement, and the mean of the difference values DHn and DLn being a channel mean value MCDn, i.e. the mean of the difference values DHn and DLn for each channel relative to the actual temperature. The method then goes on to procedure B shown in Fig. 5. In step 501 the average MD of all channel mean values MCDn is calculated. This average value is computed on the same basis as the initial average output power of all channels and accordingly may be weighted if the initial distribution of channel wavelengths in the AWG filter rendered this necessary. Accordingly if no wavelength drift has occurred on the link, i.e. if the wavelengths launched by the lasers 110 and the temperature of the demultiplexer filter 50 are unchanged, the average mean MD will be zero. In this case the comparison in step 502 results in an answer YES and the procedure is terminated. However, if this value is not equal to zero, wavelength drift must have occurred, as a result of an error either in one or more lasers or the temperature regulation of the demultiplexer filter 50, or a combination of both of these. The procedure then continues in step 503, where for each channel the initial variance value IVn is compared with the determined mean value MCDn. This step determines the number of individual channels whose wavelength has varied with respect to the initial value. The sum of these comparison results which deviate from zero is then compared with a predetermined value P in step 504 to determine the proportion of channels which have varied with respect to the initial settings. Since it is unlikely that all lasers 110 will fail simultaneously, a majority of deviating channel wavelengths will indicate that the temperature of the demultiplexer filter 50 has altered. Accordingly, The value P is selected to represent a failure in the majority of the channels used, or at least in the

proportion of the used channels which statistically are
unlikely to fail simultaneously. It may not be necessary
to perform the comparison of step 503 for all channels.
If at least a predetermined number of comparisons is
performed, this will enable the accurate determination of
how widespread any wavelength drift is, and accordingly
give an indication as to whether the temperature of the
lasers 110, the demultiplexer filter 50 or both need
adjusting to correct the wavelength.

If fewer channels than P have drifted from the initial
wavelengths, then the method turns to step 505 where, for
each channel, the channel mean values MCDn are used to
correct the wavelengths launched by the corresponding
lasers 110, preferably by altering the temperature using
the regulator 130. Conversely, if the result of the
comparison in step 504 is YES, the method continues to
step 506 where the common deviation of the channels is
determined. This value is then used in step 507 to
correct the temperature of the demultiplexer filter 50.
Once the error caused by the demultiplexer filter 50 has
been corrected, the channel mean values MCDn are
corrected in step 508 by subtracting the common value
determined in step 506. The corrected MCDn values are
then used in step 505 to correct the wavelengths launched
by the lasers, if necessary.

This procedure can, for example, be performed once every
month since it is primarily adapted to detect long
variations in wavelength. The procedure can also be
carried out during normal traffic operation without
deterioration of payload traffic. To this end, the
temperature increments used in method A in Fig. 4 are
selected to obtain a reasonable variation in wavelength
of the light signals transmitted by the demultiplexer

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filter without unduly attenuating the received signals or
provoking crosstalk in adjacent channels. For example,
for an AWG demultiplexer filter in SiO_2 on silicon,
increments of 1 °C resulting in a stepwise variation in
transmitted wavelength of 0.012nm is acceptable. It
should further be noted that the output power reduction
of 0.5dB is also given only by way of example. This value
is similarly chosen to permit accurate but easily
measurable wavelength variations without disturbance to
traffic by attenuation or crosstalk.

In an alternative embodiment of the invention steps 503
and 504 in the method B of Fig. 5 are replaced by a
single step wherein the mean variation for all channels
MD is compared with a predetermined fixed value. This
value is selected according to the number of channels
utilised and relies on the fact that a wavelength drift
due to a variation in temperature of the demultiplexer
filter 50 will result in a total mean variation n times
as large as the same drift in a single laser when n
channels are used. Since it is highly improbable that one
or more lasers will vary in wavelength to a degree which
results in the same mean value, or that their wavelengths
vary to an extent that cancels out a variation caused by
the demultiplexer filter temperature, a predetermined
fixed value can be selected to provide a reasonably
accurate gauge as to the source of the wavelength drift.

In a further embodiment of the invention, the processing
step 508 can be omitted and in its place the whole method
starting from step 401 of procedure A be repeated. Since
the drift caused by a temperature variation in the
demultiplexer has been corrected, a repeat of the whole

5   method will result in the correction of the wavelengths
     launched by the lasers, if necessary.

     The aforementioned method is particularly well adapted
     for use in an optical WDM system where pre-defined
10   wavelengths are used, however, it also has application in
     optical WDM point-to-point links where the standards laid
     down for wavelengths need not be respected. In such a
     point-to-point link, the method described with reference
     to Fig. 4 can be used to accurately match the wavelengths
15   launched by the lasers 110 to the wavelength division of
     the demultiplexer filter 50 and so enable optimal
     transmission over all channels.

CLAIMS

1. A method for controlling the wavelength of a
plurality of channels launched by optical transmission
means and received by at least one wavelength selective
element in an optical WDM link, the method including:

noting a starting value of a wavelength influencing
parameter of said wavelength selective element,

for each channel, determining a channel centre value
(MCDn) of said parameter of said wavelength selective
element at which the output power of said channel is a
maximum,

utilising said channel centre values (MCDn) to determine
a deviation between said launched wavelengths and
wavelengths selected by said wavelength selective element
and to correct said wavelength deviation at at least one
of said wavelength selective element and said optical
transmission means.

2. Method as claimed in claim 1, wherein determining
said channel centre values includes

for each channel, determining a first parameter value
(DHn) of said wavelength selective element relative to
said starting parameter value at which the power of said
channel output from said wavelength selective element
falls below a predetermined level,

for each channel, determining a second parameter value
(DLn) of said wavelength selective optical element

relative to said starting value at which the power of said channel output from said wavelength selective optical element falls below said predetermined level, and

for each channel, determining a channel mean value (MCDn) corresponding to the average of said first and second parameter values.

3. A method as claimed in claim 2, wherein said first and second parameter values are difference values (DHn, DLn) relative to said starting value.

4. A method as claimed in any one of claims 1 to 3, including calculating a mean value (MD) corresponding to the average of said channel centre values (MCDn) for all channels, and

utilising said mean value (MD) as an indicator of wavelength drift in said optical link and to adjust a deviation between said launched wavelengths and wavelengths selected by said wavelength selective element in said channels.

5. Method as claimed in claim 4, including utilising said channel centre values to determine the proportion of channels which manifest a drift in wavelength relative to the total number of channels, and

utilising said mean value (MD) to adjust a wavelength influencing parameter of said wavelength selective element when said proportion exceeds a predetermined amount.

6. A method as claimed in any one of claims 1 to 5, including:

for each of at least a predetermined number of channels comparing said channel centre value (MCDn) with a predetermined channel variance value (IVn) to obtain a difference value (Dn) indicative of a wavelength shift in said channel.

7. A method as claimed in claim 6, including determining the proportion of said channels which demonstrate a wavelength drift by summing the difference values (Dn) that deviate from zero for at least a predetermined number of channels.

8. A method as claimed in claim 6 or 7, including setting said predetermined channel variance value (IVn) as a difference between a value of said parameter of said wavelength selective element at which the output power of said channel having a predetermined nominal channel wavelength is optimised and a value of said parameter of said wavelength selective element at which the average output power of all channels having predetermined nominal wavelengths is optimised.

9. A method as claimed in any one of claims 6 to 8, including:

prior to operation of said optical link, setting the wavelengths of the optical transmission sources to predetermined nominal wavelengths,

setting said wavelength selective element to a nominal parameter value at which the output power of all said channels is optimised,

for each channel, determining a first value of said
parameter of said wavelength selective element relative
to said nominal value at which the power of said channel
output from said wavelength selective element falls below
a predetermined level,

for each channel, determining a second parameter value of
said wavelength selective optical element relative to
said nominal value at which the power of said channel
output from said wavelength selective optical element
falls below said predetermined level,

for each channel determining the mean of said first and
second parameter values, and

for each channel, utilising said mean as said
predetermined channel variance value (IVn).

10. A method as claimed in one of claims 6 to 9,
including utilising said difference values (Dn) to adjust
a wavelength influencing parameter of said wavelength
selective element.

11. A method as claimed in one of claims 6 to 9,
including for each channel utilising said difference
value (Dn) to correct the wavelength launched by said
optical transmission means.

12. A method as claimed in any one of claims 3 to 11,
wherein said mean value (MD) is a weighted average of
said first and second parameter values for all channels.

13. A method as claimed in any one of claims 1 to 12, characterised in that said parameter is the temperature of said wavelength selective element.

14. A method as claimed in any one of claims 1 to 12, characterised in that said parameter is an electrical injection current into said wavelength selective element.

15. A method as claimed in any one of claims 1 to 12, characterised in that said parameter is a mechanical movement of an optical element associated with said wavelength selective element.

16. A wavelength control arrangement for controlling the wavelengths of channels utilised in an optical WDM link including

a wavelength selective element (50) for receiving a combined optical signal including a plurality of optical channels launched by optical transmission means (10, 110) and adapted to separate at least two optical channels according to wavelength,

monitoring means (60, 70) for detecting optical signals on said channels output from said wavelength selective element (50), and

means for regulating a wavelength influencing parameter (90) associated with said wavelength selective element (50) for regulating said parameter of said wavelength selective element,

characterised by

control means (100) arranged to communicate with said regulator (90) and said monitoring means (70) and adapted to determine a parameter value of said wavelength selective element (50) for each channel relative to a starting parameter value of said wavelength selective element (50) at which the output power of said channel is a maximum, to determine a wavelength drift on the basis of said parameter values and to generate at least one control signal for rectifying wavelength.

17. An arrangement as claimed in claim 16, characterised in that said control means (100) are adapted to determine two parameter values associated with said wavelength selective element (50) for each channel at which the output power of said channel falls below a predetermined level.

18. An arrangement as claimed in claim 16 or 17, characterised in that said control means (100) comprise processing means for determining the magnitude and source of said wavelength drift.

19. An arrangement as claimed in any one of claims 16 to 18, characterised in that said wavelength selective element (50) is an arrayed waveguide grating (AWG).

20. An arrangement as claimed in any one of claims 16 to 19, characterised in that said control means (100) are adapted to communicate with said optical transmission means (10) to alter the launched wavelength using said at least one control signal.

21. An arrangement as claimed in any one of claims 16 to 20, characterised in that a regulator (130) associated with a laser (110) in said transmission means (10) is

adapted to vary a wavelength influencing parameter of said laser (110) in response to at least one control signal from said control means (100).

22. An arrangement as claimed in any one of claims 16 to 21, characterised in that said regulating means (90) are adapted to vary said parameter of said wavelength selective element (50) in response to at least one control signal from said control means (100).

23. An arrangement as claimed in any one of claims 16 to 22, characterised in that said control means (10) are adapted to communicate ·with at least one of said transmission means (10) and said regulating means (90) and monitoring means (70) via a control channel 150.

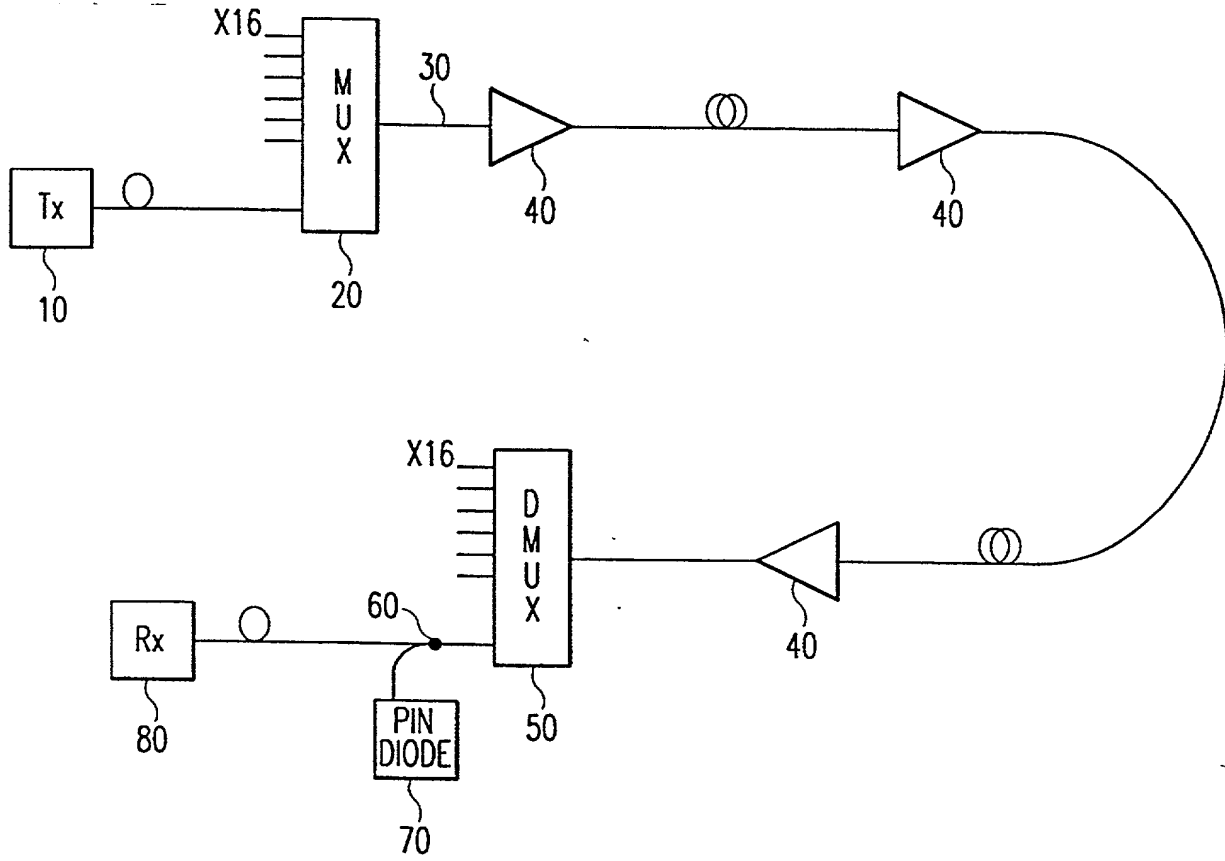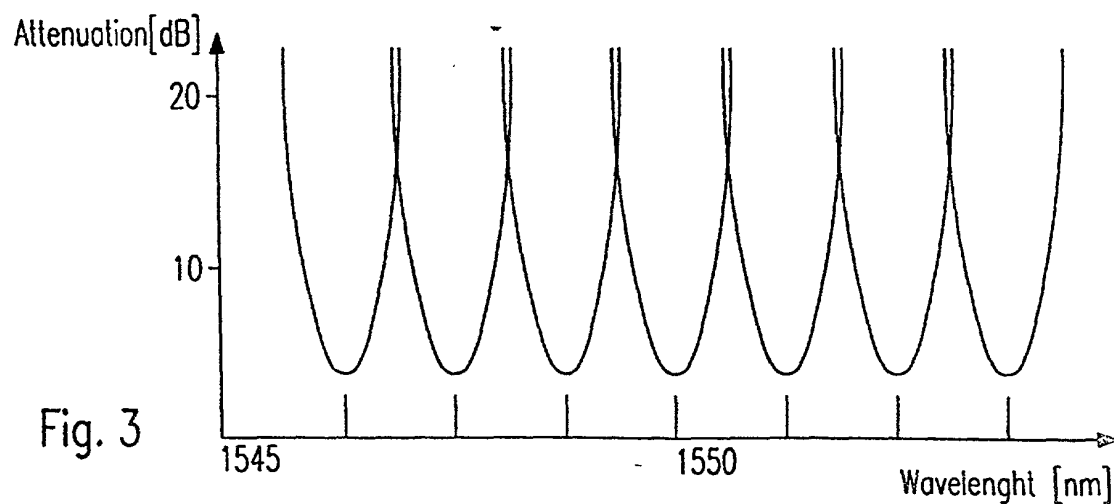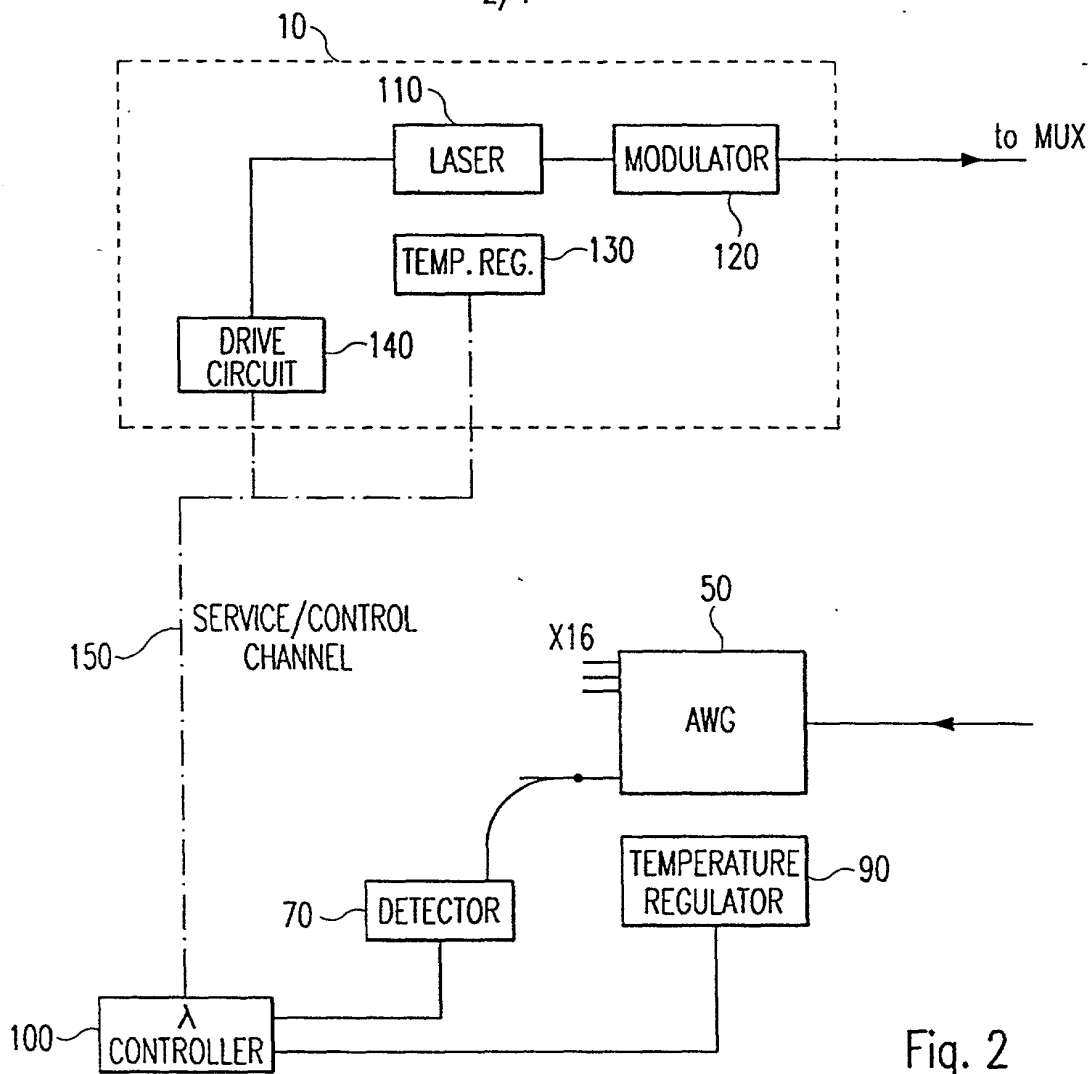24. An optical WDM link comprising a wavelength control arrangement as claimed in any one of claims 13 to 23.
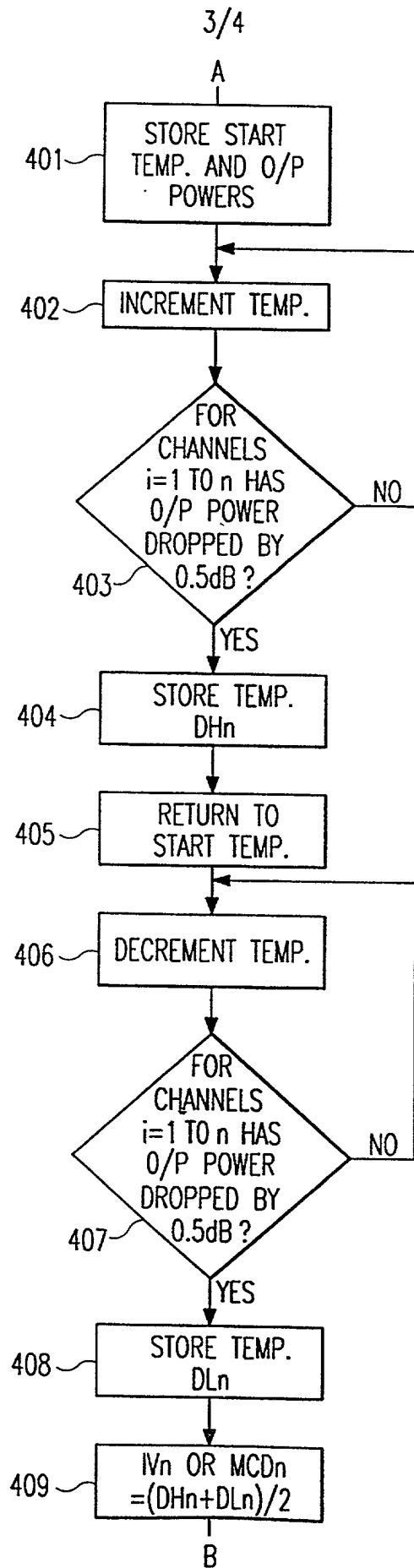
Fig. 1

Fig. 2

Fig. 3

A

401 — STORE START
TEMP. AND O/P
POWERS

402 — INCREMENT TEMP.

403 — FOR
CHANNELS
i=1 TO n HAS
O/P POWER
DROPPED BY
0.5dB ?   NO

YES

404 — STORE TEMP.
DHn

405 — RETURN TO
START TEMP.

406 — DECREMENT TEMP.

407 — FOR
CHANNELS
i=1 TO n HAS
O/P POWER
DROPPED BY
0.5dB ?   NO

YES

408 — STORE TEMP.
DLn

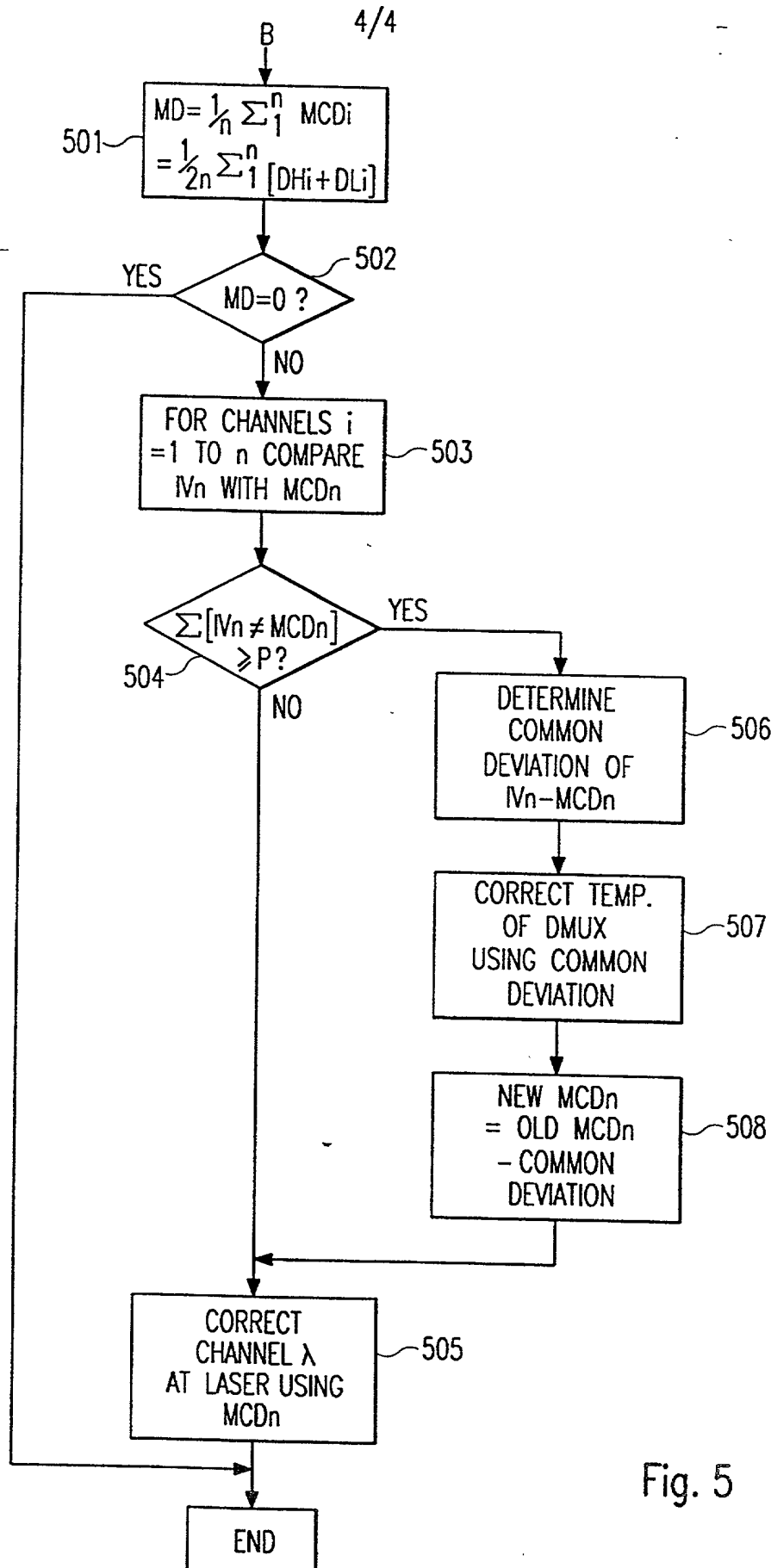409 — IVn OR MCDn
=(DHn+DLn)/2

B

Fig. 4

4/4

Fig. 5

RULES 63 AND 67 (37 C.F.R. 1.63 and 1.67)
DECLARATION AND POWER OF ATTORNEY

FOR UTILITY/DESIGN/CIP/PCT NATIONAL APPLICATIONS

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; and

I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **WAVELENGTH CONTROL IN OPTICAL WDM SYSTEMS**, the specification of which: (mark only one)

    ___   (a)   is attached hereto.

    _X_   (b)   was filed on February 13, 2000 as Application Serial No. 09/762,996

    ___   (c)   was filed as PCT International Application No. PCT/_____ on _____ and was amended on _____ (if applicable).

    ___   (d)   was filed on ___ as Application Serial No. ___ and was issued a Notice of Allowance on ___.

    ___   (e)   was filed on ___ and bearing attorney docket number ___

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above or as allowed as indicated above.

I acknowledge the duty to disclose all information known to me to be material to the patentability of this application as defined in 37 CFR § 1.56. If this is a continuation-in-part (CIP) application, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose to the Office all information known to me to be material to patentability of the application as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

I hereby claim foreign priority benefits under 35 U.S.C. § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate filed by me or my assignee disclosing the subject matter claimed in this application and having a filing date (1) before that of the application on which my priority is claimed or, (2) if no priority is claimed, before the filing date of this application:

PRIOR FOREIGN PATENTS

Number	Country	Month/Day/Year Filed	Date first laid-open or Published	Date patented or Granted	Priority Claimed Yes	No
98115369.5	EP	August 14, 1998			X	

I hereby claim the benefit under 35 U.S.C. § 120/365 of any United States application(s) listed below and PCT international applications listed above or below:

PRIOR U.S. OR PCT APPLICATIONS

Application No. (series code/serial no.)	Month/Day/Year Filed	Status(pending, abandoned, patented)
PCT/EP99/05630	03 August 1999	

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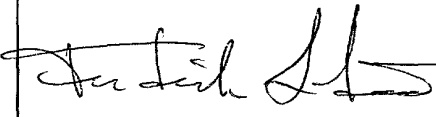
authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/organization who/which first sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct them in writing to the contrary.

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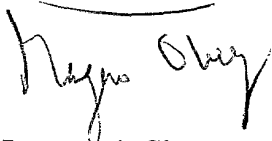Dallas, Texas 75202-2799
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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2-0 0

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